

# A TABLE OF SERIES AND PRODUCTS

**ELDON R. HANSEN**

*Lockheed Palo Alto Research Laboratory  
Palo Alto, California*

Nochrichtentechnische Bibliothek  
der Techn. Hochschule Darmstadt

Inv.-Nr.: 7219 | NT

**PRENTICE-HALL, INC.**

ENGLEWOOD CLIFFS, N. J.

**ULB Darmstadt**



18866374

# CONTENTS

## PREFACE

xvii

<b>1</b>	<b>INTRODUCTION</b>	<b>1</b>
1.1	Purpose of This Book	1
1.2	Index of Closed Forms	1
1.3	Canonical Form	2
1.4	Errors	2
1.5	References	2
1.6	Equivalent Entries	3
1.7	The Limit of Finite Sums	3
1.8	Integrals as Closed Forms	3
<b>2</b>	<b>REDUCTION TO CANONICAL FORM</b>	<b>4</b>
2.1	Introduction	4
2.2	General Rules	4
2.2.1	Removal of Rationals	4
2.2.2	Choice of Trigonometric Functions	5
2.2.3	The Factorial Function	5
2.2.3.1	Minimizing the Number of Factors	5
2.2.4	Factorials in Numerical Power Series	5
2.2.4.1	Minimizing the Number of Factors	6
2.2.4.2	An Exception	7
2.2.4.3	Products as Factorials	7
2.2.5	Choice of Dummy Index	7
2.2.6	Combining Terms	8
2.3	The Canonical Form for Numerical Power Series	8
2.3.1	Dividing Out Unnecessary Quantities	8
2.3.2	Rational Coefficients	8
2.3.3	Choice of Variable	9
2.3.4	The Choice of Origin	9
2.3.5	The Sequence of Steps	9
2.4	Multiple Series	10
2.5	Remarks	10

**3 ORDERING THE LIST** **12**

- 3.1 Introduction 12
- 3.2 Numerical Power Series 12
- 3.3 Series of Constant Terms 12

**4 MISCELLANY** **14**

- 4.1 Interchange of Order of Summation 14
- 4.2 Values of Special Numbers and Orthogonal Polynomials 15
- 4.3 Functions and Their Generalizations 15
- 4.4 Limits of Summation 15
- 4.5 Omitted Series 16
- 4.6 Asymptotic Series 16

**NUMERICAL POWER SERIES** **17**

**SERIES INVOLVING RATIONAL, FACTORIAL, AND POWER FUNCTIONS** **101**

Series (6.1.1) through (12.1.3) have summands which are rational, factorial, and power functions of the index of summation  $k$  and parameter(s). The following index for these series has a letter R and/or F and/or E in the first column according as  $k$  occurs rationally and/or factorially and/or exponentially. Similarly, the second column contains these letters to indicate the occurrence of parameter(s). If R occurs in parentheses, it is to be understood that the corresponding quantity may or may not occur rationally.

	<i>Occurrence of <math>k</math>:</i>	<i>Occurrence of Parameters:</i>	
6.1	R	(R)	101
6.2	R	E	115
6.3	R	(R), E	117
6.4	R, F	R	123
6.5	R, F	E	123
6.6	R, F	(R), F	123
6.7	R, F	R, F, E	134
6.8	R, E	R	139
6.9	R, E	R, E	142
6.10	R, F, E	R	144
6.11	R, F, E	R, F	145
6.12	R, F, E	R, E	149
6.13	R, F, E	R, F, E	149
7	F	F	151
8	F	F, E	169
9	F, E	R	169
10	F, E	R, F	170
11	E	R	211
12	E	R, E	215
13	Series Whose Summands Contain a Varying Number of Finite Products		215

## TRIGONOMETRIC SERIES

217

14 Sine Series of the Form  $\sum_k (\pm 1)^k a_k \sin(kx + y)$  217

	<i>Occurrence of <math>k</math> in <math>a_k</math>:</i>	<i>Occurrence of Parameter(s) in <math>a_k</math>:</i>	
14.1	$a_k = 1$	—	217
14.2	R	—	217
14.3	R	R	221
14.4	R	E	223
14.5	R	R, E	224
14.6	R, F	F	224
14.7	R, F	R, F	225
14.8	R, F	F, E	225
14.9	R, E	R	225
14.10	R, E	R, E	227
14.11	R, F, E	R	227
14.12	R, F, E	R, F, E	228
14.13	F	—	228
14.14	F	F	228
14.15	F, E	R	230
14.16	F, E	R, F	231
14.17	E	R	232

15 Sine Series of the Form  $\sum_k (\pm 1)^k a_k [\sin(kx + y)]^p$  234

	<i>Occurrence of <math>k</math> in <math>a_k</math>:</i>	<i>Occurrence of Parameter(s) in <math>a_k</math>:</i>	
15.1	$a_k = 1$	—	234
15.2	R	—	235
15.3, 15.4	R	E	235
15.5	E	R	236
15.6	R, E	(R, E)	236
15.7	F, E	R	237
15.8	F, E	R, F	237

## 16 Miscellaneous Sine Series 237

17 Cosine Series of the Form  $\sum_k (\pm 1)^k a_k \cos(kx + y)$  238

	<i>Occurrence of <math>k</math> in <math>a_k</math>:</i>	<i>Occurrence of Parameter(s) in <math>a_k</math>:</i>	
17.1	$a_k = 1$	—	238
17.2	R	—	238
17.3	R	R	242
17.4	R	E	244
17.5	R	R, E	245
17.6	R, F	F	245
17.7	R, F	R, F	245
17.8	R, F	F, E	246
17.9	R, E	R	246
17.10	R, E	R, E	248
17.11	R, F, E	R	248
17.12	R, F, E	R, F, E	249
17.13	F	—	249
17.14	F	F	249
17.15	F, E	R	253
17.16	F, E	R, F	254
17.17	E	R	255

18	Cosine Series of the Form $\sum_k (\pm 1)^k a_k [\cos(kx + y)]^m$	256
	<i>Occurrence of k in a<sub>k</sub>:</i>	
18.1	$a_k = 1$	256
18.2	<b>R</b>	257
18.3	<b>R, E</b>	257
18.4	<b>F, E</b>	257
19	Miscellaneous Cosine Series	257
20	Tangent Series of the Form $\sum_k (\pm 1)^k \tan(kx + y)$	258
21	Tangent Series of the Form $\sum_k [\tan(kx + y)]^m$	258
22	Miscellaneous Tangent Series	259
23	Cosecant Series of the Form $\sum_k (\pm 1)^k \csc(kx + y)$	259
24	Cosecant Series of the Form $\sum_k [\csc(kx + y)]^m$	259
25	Miscellaneous Cosecant Series	260
26	Secant Series of the Form $\sum_k \sec(kx + y)$	260
27	Secant Series of the Form $\sum_k [\sec(kx + y)]^m$	261
28	Miscellaneous Secant Series	261
29	Cotangent Series of the Form $\sum_k (\pm 1)^k \cot(kx + y)$	262
30	Cotangent Series of the Form $\sum_k [\cot(kx + y)]^m$	262
31	Series of the Form $\sum_k a_k \sin(kx + y) \sin(kz + w)$	262
32	Series of the Form $\sum_k a_k \sin(kx + y) \cos(kz + w)$	264
33.1	Series of the Form $\sum_k a_k \sin(kx + y) \tan(kz + w)$	265
33.2	Series of the Form $\sum_k \sin(kx + y) \csc(kz + w)$	265
33.3	Series of the Form $\sum_k \sin(kx + y) \cot(kz + w)$	265
34	Series of the Form $\sum_k a_k \cos(kx + y) \cos(kz + w)$	265
35	Other Series of the Form $\sum_k a_k \text{trig}(kx + y) \text{trig}(kz + w)$	266
36	Miscellaneous Series of Products of Two Trigonometric Functions	267
37	Series Containing a Product of Three Trigonometric Functions	268
38	Series Containing a Product of Four Trigonometric Functions	269
39	Series Containing a Product of Six Trigonometric Functions	269
40	Series Involving Many Trigonometric Functions	270
41.1–41.12	Series Whose Summands Are Rational Functions of Trigonometric Functions	270
41.13	Miscellaneous Series Involving Trigonometric Functions	275

**INVERSE TRIGONOMETRIC FUNCTIONS 276**

42	Series Involving the Arctangent	276
----	---------------------------------	-----

**HYPERBOLIC FUNCTIONS 279**

43.1	Series of the Form $\sum_k a_k \sinh(kx + y)$	279
43.2	Miscellaneous Series Involving sinh	280
43.3	Series of the Form $\sum_k a_k \cosh(kx + y)$	281
43.4	Miscellaneous Series Involving cosh	282
43.5	Series of the Form $\sum_k a_k \tanh(kx + y)$	282
43.6	Miscellaneous Series Involving tanh	283
43.7	Series Involving csch	283
43.8	Series Involving sech	284
43.9	Series Involving coth	285
43.10	Miscellaneous Series Involving Hyperbolic Functions	286

**THE LOGARITHMIC FUNCTION 287**

44.1–44.7	Series of the Form $\sum_k a_k \log(kx + y)$	287
44.8	Series of the Form $\sum_k a_k \log[p(k)/q(k)]$ Where $p$ and $q$ are Polynomials	289
44.9	Series of the Form $\sum_k \left( b_k + a_k \log \frac{kx + y}{kz + w} \right)$	290
44.10	Series of the Form $\sum_k a_k \log[\Gamma(kx + y)]$	290
44.11	Series Involving the Logarithm of a Trigonometric Function	291
44.12	Series of Powers of the Log Function	291
44.13	Miscellaneous Series Involving the Log Function	291

**ORTHOGONAL POLYNOMIALS**

45	Series Involving Jacobi Polynomials	292
46	Series Involving Legendre Polynomials	300
	Series of the Form $\sum_{k=0}^n a_k P_{r-k}(x)$	300
	Series of the Form $\sum_k (\pm 1)^k a_k P_{kn+m}(x)$	300

*Occurrence of k in a<sub>k</sub>:*

46.1	$a_k = 1$	300
46.2	R	300
46.3	E	302
46.4	F	302
46.5	R, E	302
46.6	R, F	303
46.7	F, E	304
46.8	Series of the Form $\sum_k a_k P_{kn+m}(x) P_{kr+s}(y)$	305
46.9	Series of the Form $\sum_k a_k P_k(x) P_k(y) P_k(z)$	307
46.10	Miscellaneous Series Involving Legendre Polynomials	307
47	Series Involving Gegenbauer (Ultraspherical) Polynomials	307
	Series of the Form $\sum_{k=0}^n a_k C_{r-k}^{(q)}(x)$	307
	Series of the Form $\sum_k (\pm 1)^k a_k C_{kn+m}^{(q)}(x)$	307

*Occurrence of k in a<sub>k</sub>:*

47.1	R	307
47.2	E	307
47.3	R, E	308
47.4	R, F	308
47.5	F, E	309
47.6	Series of the Form $\sum_k a_k C_{km+n}^{(p)}(x) C_{kr+s}^{(q)}(y)$	310
47.7	Series of the Form $\sum_k a_k C_{kn+m}^{(kp+q)}(x) C_{kr+s}^{(ka+b)}(y) C_{ku+v}^{(d)}(z)$	312
48	Series Involving Laguerre and Generalized Laguerre Polynomials	312
	Series of the Form $\sum_{k=0}^n a_k L_{r-k}^{(b+kc)}(x)$	312
	Series of the Form $\sum_k (\pm 1)^k a_k L_{km+n}^{(c)}(x)$	312

*Occurrence of k in a<sub>k</sub>:*

48.1	$a_k = 1$	312
48.2	R	312
48.3	F	313
48.4	E	314
48.5	R, F	314
48.6	R, E	315
48.7	F, E	315
48.8	R, F, E	316
	Series of the Form $\sum_{k=0}^n a_k L_m^{(b-kc)}(x)$	316
	Series of the Form $\sum_k (\pm 1)^k a_k L_m^{(b+kc)}(x)$	316

*Occurrence of k in a<sub>k</sub>:*

48.9	$a_k = 1$	316
48.10	F	316
48.11	E	316
48.12	R, E	317
48.13	F, E	317
48.14	R, F, E	318
	Series of the Form $\sum_{k=0}^n a_k L_{r-k}^{(b+kc)}(x)$	318
	Series of the Form $\sum_k (\pm 1)^k a_k L_{r+ks}^{(b+kc)}(x)$	318

*Occurrence of k in a<sub>k</sub>:*

48.15	$a_k = 1$	318
48.16	F	318
48.17	E	318
48.18	R, E	319
48.19	F, E	319
48.20	R, F, E	320

48.21	Series of the Form $\sum_k a_k L_{ku+m}^{(b)}(x) L_{kr+s}^{(c)}(y)$	321
48.22	Series of the Form $\sum_k a_k L_n^{(k,p+q)}(x) L_m^{(k,u+v)}(y)$	323
48.23	Series of the Form $\sum_k a_k L_{kn+m}^{(kr+s)}(x) L_{kp+q}^{(ku+v)}(y)$	323
48.24	Series Involving Several Laguerre Polynomials	324
48.25	Miscellaneous Series Involving Laguerre Polynomials	325
49	Series Involving Hermite Polynomials	325
	Series of the Form $\sum_{k=0}^n a_k H_{r-ks}(x)$	325
	Series of the Form $\sum_k (\pm 1)^k a_k H_{km+n}(x)$	325

*Occurrence of k in a<sub>k</sub>:*

49.1	F	325
49.2	E	326
49.3	R, E	326
49.4	F, E	326
49.5	R, F, E	328
49.6	Series of the Form $\sum_k a_k H_{km+n}(x) H_{kr+s}(y)$	329
49.7	Miscellaneous Series in Hermite Polynomials	330

**BERNOULLI, EULER, AND STIRLING POLYNOMIALS AND NUMBERS AND NEUMANN POLYNOMIALS**

**331**

50	Series Involving Bernoulli and Generalized Bernoulli Polynomials and Numbers	331
	Series of the Form $\sum_{k=0}^n a_k B_{r-sk}(x)$	331
	Series of the Form $\sum_k (\pm 1)^k a_k B_{km+n}(x)$	331

*Occurrence of k in a<sub>k</sub>:*

50.1	F	331
50.2	E	332
50.3	R, F	332
50.4	R, E	332
50.5	F, E	333
50.6	R, F, E	337
50.7	Series of the Form $\sum_k a_k B_m(x + yk)$	338
50.8	Series of the Form $\sum_k a_k B_{km+n}^{(r)}(x)$	339
	Series of the Form $\sum_{k=0}^n a_k B_{r-km}^{(k,p+q)}(x)$	340
50.9	Series of the Form $\sum_k a_k B_{km+n}^{(r \pm k)}(x)$	341
50.10	Series of the Form $\sum_k a_k B_{km+n}^{(r-k)}(kx)$	341
50.11	Series of the Form $\sum_k a_k B_{km+n}(x) B_{kr+s}(y)$	341
50.12	Series of the Form $\sum_k a_k B_{km+n}^{(u)}(x) B_{kr+s}^{(v)}(y)$	343
51	Series Involving Euler and Generalized Euler Polynomials and Numbers	343
	Series of the Form $\sum_{k=0}^n a_k E_{r-sk}(x)$	343
	Series of the Form $\sum_k (\pm 1)^k a_k E_{km+n}(x)$	343

*Occurrence of k in a<sub>k</sub>:*

51.1	F	343
51.2	E	343
51.3	F, E	344
51.4	R, F, E	345
51.5	Series of the Form $\sum_k a_k E_m(x + ky)$	345
51.6	Series of the Form $\sum_k a_k E_{km+n}(x) E_{kr+s}(y)$	346
51.7	Series of the Form $\sum_k a_k E_{km+n}^{(r)}(x)$	346
51.8	Series of the Form $\sum_k a_k E_k^{(m)}(x) E_{n-k}^{(r)}(y)$	347
52	Series Involving Stirling Numbers	347
	Series of the Form $\sum_k a_k S_{m-k}^{(r)}$ and $\sum_k a_k \mathfrak{S}_{m-k}^{(r)}$	347
52.1	Series of the Form $\sum_k a_k S_{k+r}^{(s)}$ and $\sum_k a_k \mathfrak{S}_{k+r}^{(s)}$	347

Series of the Form $\sum_{k=0}^n a_k S_m^{(r-ks)}$ and $\sum_{k=0}^n a_k \mathfrak{S}_m^{(r-ks)}$	348
52.2 Series of the Form $\sum_k a_k S_r^{(k+s)}$ and $\sum_k a_r \mathfrak{S}_r^{(k+s)}$	348
Series of the Form $\sum_{k=0}^n a_k S_m^{(kr+s)}$ and $\sum_{k=0}^n a_k \mathfrak{S}_{m-k}^{(kr+s)}$	351
52.3 Series of the Form $\sum_k a_k S_{n+mk}^{(r+sk)}$ and $\sum_k a_k \mathfrak{S}_{n+mk}^{(r+sk)}$	351
52.4 Series Involving Two Stirling Numbers	352
53 Series Involving the Neumann Polynomial	353

**SERIES INVOLVING HIGHER TRANSCENDENTAL FUNCTIONS 355**

54 Series Involving the Riemann and Generalized Riemann Zeta Functions	355
Series of the Form $\sum_k (\pm 1)^k a_k \zeta(kx + y)$	355

*Occurrence of k in a<sub>k</sub>:*

54.1	$a_k = 1$	355
54.2	R	355
54.3	E	355
54.4	F	356
54.5	R, E	356
54.6	F, E	357
54.7 Miscellaneous Series Involving the Riemann Zeta Function		357
Series of the Form $\sum_k a_k \zeta(kx + y, a)$		358

*Occurrence of k in a<sub>k</sub>:*

54.8	$a_k = 1$	358
54.9	R	358
54.10	E	358
54.11	R, E	358
54.12	F, E	359
54.13 Series of the Form $\sum_k a_k \zeta(s, ka + b)$		360
55 Series Involving the Psi Function		360
Series of the Form $\sum_k (\pm 1)^k a_k \psi(kx + y)$ and Linear Combinations of Such Series		360

*Occurrence of k in a<sub>k</sub>:*

55.1	$a_k = 1$	360
55.2	R	360
55.3	E	361
55.4	F	361
55.5	R, F	362
55.6	R, E	362
55.7	F, E	363
55.8 Miscellaneous Series Involving the Psi Function		366
55.9 Series Involving Derivatives of the Psi Function		366
56 Series Involving Legendre Functions		367
56.1 Series of Legendre Functions of the Form $\sum_k a_k P_{kp+q}^{(r)}(x)$ or $\sum_k a_k \mathfrak{P}_{kp+q}^{(r)}(z)$		367
56.2 Series of Legendre Functions of the Form $\sum_k a_k Q_{kp+q}^{(u)}(x)$ or $\sum_k a_k \mathfrak{Q}_{kp+q}^{(u)}(z)$		370
56.3 Series of Legendre Functions of the Form $\sum_k a_k P_p^{(q+rk)}(x)$ or $\sum_k a_k \mathfrak{P}_p^{(q+rk)}(z)$		371
56.4 Series of Legendre Functions of the Form $\sum_k a_k Q_p^{(q+k)}(x)$ or $\sum_k a_k \mathfrak{Q}_p^{(q+k)}(z)$		372
56.5 Series of Legendre Functions of the Form $\sum_k a_k P_{kp+q}^{(ku+v)}(x)$		372
56.6 Series of Legendre Functions of the Form $\sum_k a_k P_{kp+q}^{(b)}(x) P_{ku+v}^{(c)}(y)$ and Similar Series Involving $\mathfrak{P}$ , $\mathfrak{Q}$ , and $\mathfrak{Q}$		373
56.7 Series of the Form $\sum_k a_k P_r^{(kp+q)}(x) P_s^{(ku+v)}(y)$ and Similar Series Involving $\mathfrak{P}$ , $\mathfrak{Q}$ , and $\mathfrak{Q}$		374
56.8 Series Involving Three Legendre Polynomials or Functions		377
57 Series of Bessel Functions of the First and Second Kinds		377



Series of the Form $\sum_k (\pm 1)^k a_k Z_{kp+q}(z)$ (Neumann Series, etc.)			377
	<i>Occurrence of <math>k</math> in <math>a_k</math>:</i>	<i>Occurrence of Parameters in <math>a_k</math>:</i>	
57.1	$a_k = 1$	—	377
57.2	R	—	379
57.3	F	—	382
57.4	R	R	382
57.5	R	E	384
57.6	E	R	385
57.7	F	F	386
57.8	R, F	—	386
57.9	R, F	F	386
57.10	R, E	R	387
57.11	F, E	R	387
57.12	R	R, E	388
57.13	R, F	R, F	388
57.14	F, E	R, F	390
57.15	R, F, E	R	391
57.16	R, F, E	R, F	392
Series of the Form $\sum_k (\pm 1)^k a_k Z_{kp+q}(z) W_{kr+s}(t)$ (Neumann Series, etc.)			392
	<i>Occurrence of <math>k</math> in <math>a_k</math>:</i>	<i>Occurrence of Parameters in <math>a_k</math>:</i>	
57.17	$a_k = 1$	—	392
57.18	R	—	395
57.19	R	E	397
57.20	E	R	397
57.21	R	R	398
57.22	F, E	R	399
57.23	F	F	399
57.24	R, F	F	400
57.25	R, F	R, F	400
57.26 Series of the Form $\sum_k a_k J_{kp+q}(z) J_{kr+s}(z) J_{ku+v}(w)$			401
Series of the Form $\sum_k (\pm 1)^k a_k Z_a(kx + y)$ (Schlömlich Series)			401
	<i>Occurrence of <math>k</math> in <math>a_k</math>:</i>	<i>Occurrence of Parameters in <math>a_k</math>:</i>	
57.27	$a_k = 1$	—	401
57.28	R	—	402
57.29	R	R	402
57.30	R	E	402
57.31	E	R	403
57.32	R	R, E	403
57.33	R, E	R, E	404
57.34 Series of the Form $\sum_k a_k J_a(kx + y) J_b(kz + w)$ (Schlömlich Series, etc.)			404
57.35 Series of the Form $\sum_k a_k \prod_{i=1}^n J_b(kz_i)$			406
57.36 Series of the Form $\sum_k a_k J_{ka+b}(kz + t)$ (Kapteyn Series, etc.)			406
57.37 Series of the Form $\sum_k a_k J_{k+a}(kz + t) J_{k+b}(kz + t)$ (Kapteyn Series, etc.)			408
57.38 Miscellaneous Series in Bessel Functions of the First Kind			409
57.39 Series Involving Higher Derivatives of Bessel Functions of the First Kind			411
58 Series of Modified Bessel Functions of the First and Second Kinds			411
Series of the Form $\sum_k (\pm 1)^k a_k S_{kp+q}(z)$			411
	<i>Occurrence of <math>k</math> in <math>a_k</math>:</i>	<i>Occurrence of Parameters in <math>a_k</math>:</i>	
58.1	$a_k = 1$	—	411
58.2	R	—	412
58.3	R	R	413
58.4	R	E	413
58.5	E	R	413
58.6	F	F	414
58.7	R, E	R	414
58.8	F, E	R	414
58.9	R, F	R, F	415
58.10	R, F, E	R	416
58.11	R, F, E	R, F	416
58.12	Misc.	—	417

58.13	Series of the Form $\sum_k a_k \vartheta_{kp+q}(z) \mathfrak{J}_{kr+s}(w)$	417
58.14	Series of the Form $\sum_k (\pm 1)^k K_n(kz)$	418
59.1	Series Involving Hankel Functions	418
59.2	Series Involving Struve Functions	418
59.3	Series Involving Anger-Weber Functions	419
60	Series Involving the Parabolic Cylinder Function	421
61.1	Series Involving the Incomplete Gamma Function	422
61.2	Series Involving the Complement of the Incomplete Gamma Function	422
62	Series Involving the Incomplete Beta Function	423
63	Series Involving the Error Function (with Imaginary Argument)	423
64.1	Series Involving the Exponential Integral	423
64.2	Series Involving the Sine Integral	424
64.3	Series Involving the Cosine Integral	424
65	Series Involving the Hypergeometric Function	424
65.1-65.5	Series of the Form $\sum_k a_k {}_2F_1(k\alpha + \lambda, k\beta + \mu; k\gamma + \nu; x)$	424
65.6	Series Involving Two Hypergeometric Functions	429
66	Series Involving the Confluent Hypergeometric Function	430
66.1-66.4	Series of the Form $\sum_k a_k {}_1F_1(k\alpha + \mu; k\beta + \nu; x)$	430
66.5	Series Involving Two Confluent Hypergeometric Functions	432
67.1	Series Involving the Generalized Hypergeometric Function	433
67.2	Series Involving Two Generalized Hypergeometric Functions	436

**SERIES INVOLVING TWO OR MORE FUNCTIONS 438**

68.1	Series Involving Trigonometric and Hyperbolic Functions	438
68.2	Series Involving Trigonometric and Logarithmic Functions	440
69	Series Involving Trigonometric Functions and Legendre Polynomials	441
70	Series Involving Trigonometric Functions and Laguerre Polynomials	441
71	Series Involving Trigonometric Functions and Hermite Polynomials	442
72	Series Involving Trigonometric Functions and Bernoulli Numbers	442
73	Series Involving the Logarithm Function and Bernoulli Polynomials	442
74	Series Involving Trigonometric and Higher Transcendental Functions	443
74.1-74.3	Series Involving One Trigonometric Function and One Bessel Function or Modified Bessel Function	443
74.1	Schlömilch and Related Series	443
74.2	Neumann Series	447
74.3	Kapteyn Series	451
74.4	Series Involving Two Trigonometric Functions and One Modified Bessel Function	451
74.5-74.6	Series Involving One Trigonometric Function and Two Bessel or Modified Bessel Functions	452
74.5	Schlömilch and Related Series	452
74.6	Neumann Series and Related Series	453
74.7	Series Involving Trigonometric and Struve Functions	456
74.8	Series Involving Trigonometric and Anger-Weber Functions	456
74.9	Series Involving a Trigonometric Function and a Legendre Function	457
74.10	Series Involving a Trigonometric Function and Two Legendre Functions	459
74.11	Series Involving Trigonometric and Parabolic Cylinder Functions	461
74.12	Series Involving Trigonometric and Generalized Riemann Zeta Functions	461
74.13	Series Involving Trigonometric and Psi Functions	461
74.14	Series Involving Trigonometric and Confluent Hypergeometric Functions	461
75	Series Involving Hyperbolic and Bessel or Modified Bessel Functions	461
76	Series Involving Two Orthogonal Polynomials	462
76.1	Series Involving Legendre and Hermite Polynomials	462
76.2	Series Involving Legendre and Laguerre Polynomials	463
76.3	Series Involving Gegenbauer and Laguerre Polynomials	463
76.4	Series Involving Hermite and Laguerre Polynomials	463
76.5	Series Involving Jacobi and Laguerre Polynomials	464
77.1	Series Involving Bernoulli and Euler Polynomials or Numbers	464
77.2	Series Involving Bernoulli Polynomials or Numbers and Stirling Numbers	465
78	Series Involving Legendre Functions and Gegenbauer Polynomials	466
79.1	Series Involving Bessel or Modified Bessel Functions and Legendre Polynomials	466

79.2	Series Involving Bessel or Modified Bessel Functions and Gegenbauer Polynomials	467
79.3	Series Involving Bessel or Modified Bessel Functions and Jacobi Polynomials	468
79.4	Series Involving Bessel or Modified Bessel Functions and Laguerre Polynomials	469
79.5	Series Involving Bessel Functions and Chebyshev Polynomials	469
80	Series Involving Orthogonal Polynomials and (Ordinary, Confluent, or Generalized) Hypergeometric Functions	470
80.1	Legendre Polynomials	470
80.2	Gegenbauer Polynomials	471
80.3	Hermite Polynomials	471
80.4	Laguerre Polynomials	472
80.5	Jacobi Polynomials	473
81	Series Involving Bernoulli Numbers and Legendre Polynomials	473
82.1	Series Involving Bernoulli Polynomials and the Riemann Zeta Function	473
82.2	Series Involving Stirling Numbers and the Riemann Zeta Function	473
83.1	Series Involving Bessel Functions and Neumann Polynomials	474
83.2	Series Involving Bessel Functions and Kapteyn Polynomials	474
84	Series Involving Bessel or Modified Bessel Functions and Psi Functions	474
85.1	Series Involving Bessel and Modified Bessel Functions	475
85.2	Series Involving Bessel and Legendre Functions	475
86	Series Involving Bessel or Modified Bessel and Generalized Hypergeometric Functions	476
87.1	Series Involving Hypergeometric and Confluent Hypergeometric Functions	477
87.2	Series Involving Hypergeometric and Generalized Hypergeometric Functions	477
87.3	Series Involving Confluent and Generalized Hypergeometric Functions	477

**MULTIPLE SERIES 478**

88.1	Expansions of Trigonometric Functions	478
88.2	Inverse Trigonometric Functions	480
88.3	Hyperbolic Functions	480
88.4	Exponential Function	480
88.5	Exponential Functions with Argument Involving a Trigonometric Function	480
88.6	Logarithmic Function	481

**PRODUCTS 482**

89	Products of Rational Functions	482
	Products of the Form $\prod_k p(k)$ Where $p(k)$ is a Polynomial in $k$ of Degree $s$	482
89.1	$s = 1$	482
89.2	$s = 2$	482
89.3	$s$ Arbitrary	482
	Products of the Form $\prod_k \left[ 1 + \frac{a + (-1)^k b}{p(k)} \right]$ Where $p(k)$ is a Polynomial in $k$ of Degree $r$	483
89.4	$r = 1$	483
89.5	$r = 2$	483
89.6	$r = 3$	484
89.7	$r = 4$	485
89.8	$r$ Unspecified	485
	Products of the Form $\prod_k \left[ 1 + \frac{a}{p(k)} \right] \left[ 1 + \frac{b}{q(k)} \right]$ Where $p(k)$ and $q(k)$ are Polynomials in $k$ of Degree $r$	486
89.9	$r = 1$	486
89.10	$r = 2$	486
89.11	$r$ Unspecified	487
89.12	Products of the Form $\prod_k \left[ 1 + \frac{b + ka}{(kx + y)^2} \right] \left[ 1 + \frac{c - ka}{(kx + z)^2} \right]$	487
89.13	Products of the Form $\prod_k \left( 1 + \frac{c}{ka + b} \right) \left( 1 + \frac{z}{kx + y} \right) \left( 1 + \frac{t}{kr + s} \right)$	487
89.14	Products of the Form $\prod_k \left( 1 + \frac{c}{ka + b} \right) \left( 1 + \frac{z}{kx + y} \right) \left( 1 + \frac{t}{kr + s} \right) \left( 1 + \frac{w}{ku + v} \right)$	487

89.15	Products Involving an Unspecified Number of Factors	487
89.16	Products of the Form $\prod_k (kx + y)^k$	488
89.17	Products Involving Factors of the Form $\left[1 + \frac{a}{p(k)}\right]^{ku+v}$ Where $p(k)$ is a Polynomial in $k$	488
	Products of the Form $\prod_k (b + ax^{k p+q})$	488
89.18	$p = 1, q = 0$	488
89.19	$p = 1, q$ Unspecified	490
89.20	$p = 2, q = 0$	490
89.21	$p = 2, q = 1$	491
89.22	Products of the Form $\prod_k (1 + ax^{k p+q})^m$	491
	Products of the Form $\prod_k \left(\frac{1 + ax^{k p+q}}{1 + bx^{k r+s}}\right)^m$ and Similar Products	492
89.23	$m = 1$	492
89.24	$m = 2$	493
89.25	$m = 4$	493
89.26	Products of the Form $\prod_k [1 + ax^{k p+q} + x^{2(k p+q)}]$	493
89.27	Products of the Form $\prod_k (1 + ax^{k p+q})(1 + bx^{k r+s})$	494
89.28	Products of the Form $\prod_k (1 + ax^{k p+q})(1 + bx^{k r+s})(1 + cx^{k u+v})$	494
89.29	Products of the Form $\prod_k \frac{1 + ax^{k p+q} + x^{2(k p+q)}}{1 + ax^{k r+s} + x^{2(k r+s)}}$ and Similar Products	495
89.30	Products Involving $x^{2k}$	495
90	Products Involving the Gamma Function (or Factorials)	496
91	Products Involving Trigonometric Functions With Arguments of the Form $kx + y$	496
91.1	The Sine Function	496
91.2	The Cosine Function	498
91.3	The Tangent Function	500
91.4	The Cosecant Function	501
91.5	The Secant Function	501
91.6	The Cotangent Function	502
91.7	Products Involving Trigonometric Functions with Arguments of the Form $\frac{\pi}{k+a}$	503
91.8	Products Involving Trigonometric Functions with Arguments of the Form $2^{\pm kx}$ (and Similar Arguments)	503
92	Products Involving Hyperbolic Functions	504
93	Products Involving the Exponential Function	504
	<b>INDEX OF SYMBOLS</b>	<b>506</b>
	<b>INDEX OF ELEMENTARY FUNCTIONS EXPANDED AS A SERIES OR PRODUCT</b>	<b>513</b>
	<b>BIBLIOGRAPHY</b>	<b>520</b>